Optimization of Medical Imaging Display Systems Using the Channelized Hotelling Observer

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I. Introduction

Medical-imaging systems are designed to aid medical specialists in a specific task. In order to satisfy the quality preferences of a *human observer*, the optimization of medical-imaging systems has to include measurements of human performance and has to use these results for final tuning of the physical parameters of the system. To measure human performance it is necessary to conduct the psychophysical studies and have the human medical specialist asses the quality of the system. However, these studies are very costly in terms of both time and money. In this research, we investigate *numerical observer models* and the benefits of using these as a supplement, or even as a substitute for human observer studies.

II. Background

A. Signal Detection Theory

Signal detection theory [1] refers to a binary classification task where the hypotheses correspond to the conditions of the signal is present (H_1) and the signal is absent (H_0). The observer decides which of the two hypotheses is true by making the decision D_1 to decide that H_1 is true or D_0 to decide that H_0 is true (Fig.1). Clearly, in binary classification the decision may be either correct or wrong. The rate of classification error is influenced by multiple factors: the signal, the background and the knowledge of the observer – a more knowledgeable observer is likely to make decisions with less degree of error.

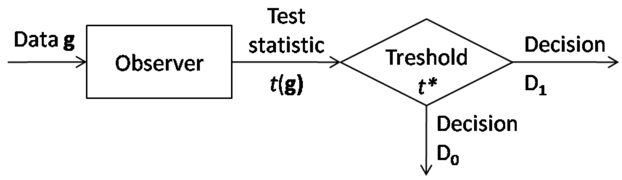

Fig. 1 Model observer in a detection task

B. Channelized Hotelling Observer (CHO)

The focus of this research is a channelized Hotelling observer (CHO) [2]. In general, channelized models compute the correlation between each channel and the image data while significantly reducing the dimensionality of the problem. Summary response of all channels is used to determine the classification decision. The channels are chosen based on a priori knowledge of the signal and can be seen as linear operators. We investigate different types of channels, e.g. Laguerre-Gauss (LG) (Fig.2), difference of Gaussian and steerable pyramid channels.

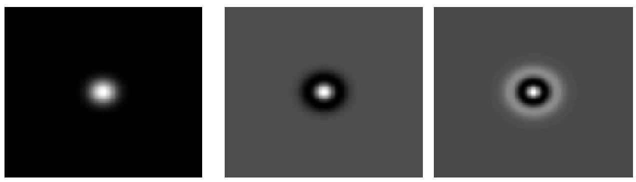

Fig. 2 Example of LG channels

As often is the case in binary classification studies, we use the area under the ROC curve (AUC) as a figure of merit when estimating the performance of the CHO.

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C. Multi-Reader Multi-Case Study

The paradigm of MRMC is widely used to estimate the mean performance of an observer in the context of measuring the AUC. In particular, we use the assessment strategy based on a fully crossed study design which assumes that every reader reads every case which in the clinical practice would correspond to every doctor diagnosing every patient. Obviously, the results of such study are affected by a particular selection of the participating readers.

III. RESEARCH METHODOLOGY

A. Image data

The availability of real image data is often limited in medical imaging research. Hence, simulated images are commonly used in the experiments.

The images are created in several steps (Fig.3). First, the background images are generated to simulate healthy (signal-absent) cases. In Fig.4 an example of well-known clustered-lumpy background (CLB) is given. Next, simulated nodules with different contrasts and diameters are digitally superimposed on the background images to create the set of diseased (signal-present) images. The nodules are usually Gaussian signals, circular Samei polynomials or "designer nodules".

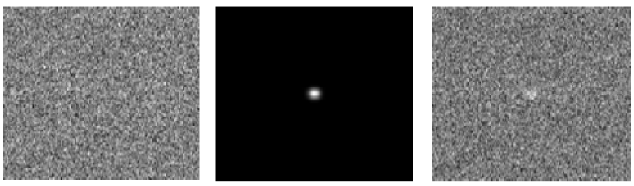

Fig. 3 Image generation: a) background image b) signal image, and c) signal-present image

B. Observer Performance Experiments

The performance of the CHO is evaluated in MRMC studies. Channel parameters are tuned to best fit the given data set in a classification task.

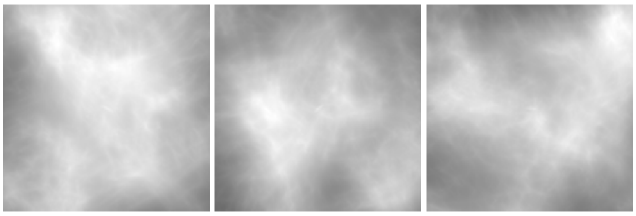

Fig. 4 Simulated CLB images

C. Data Analysis

As a standard methodology, the area under the ROC curve is used to process the results of the CHO performance experiments. Experimental AUC data is averaged across the readers and accuracy of reader-averaged AUC is assessed using different mechanisms, e.g. the "one-shot" analysis [3].

IV. CONCLUSIONS

In this work, we will investigate the performance of a CHO with different types of channels in the range of medical modality detection tasks. Especially, we will look at a model observer which is able of classifying dynamic sequences of medical images which has not been widely explored so far.

Finally, we will continuously estimate the uncertainty associated with the obtained measurements not to disregard the real-world constraint of a finite sample size, i.e. limited size of clinical image data sets.

ACKNOWLEDGEMENTS

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